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"..... per litora spargite muscum,
Naiades, et circùm vitreos considite fontes :
Pollice virgineo teneros hìc carpite flores :
Floribus et pictum, divæ, replete canistrum.
At vos, o Nymphæ Craterides, ite sub undas ;
Ite, recurvato variata corallia trunco
Vellite muscosis e rupibus, et mihi conchas
Ferte, Deæ pelagi, et pingui conchylia succo."
N. Parthenii Giannettasii Ecl. 1.

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I.—*Observations on the Reproduction of certain* Nostochineæ.

By M. G. THURET*.

[With a Plate.]

THE *Nostochineæ* are among those tribes of Algæ of whose reproduction we know least. About thirteen years ago I described the curious phænomena accompanying the reproduction of an aquatic *Nostoc*†. Since then, no one appears to have taken up this subject; and M. Fischer‡, in his memoir on this family, remarks that my observations have remained isolated up to this time.

But the mode of reproduction which I made known is certainly not peculiar to one species. I cannot doubt that it will be found in all, when it is sought for with a little attention and perseverance. Already the correctness of this assertion has been

* Translated from Mém. de la Société des Sc. Nat. de Cherbourg, Aug. 1857.—A. H.

† Ann. des Sc. Nat. 3 sér. ii. p. 319 (1844). The plant forming the object of that paper was not the true *Nostoc verrucosum*, but a neighbouring species which M. Mougeot had published under this name (Stirpes Crypt. Vog. Rhen. fasc. viii. no. 798), and which now bears that of *Nostoc Mougeotii*, Bréb. (Menegh. Monogr. Nostochin. Italic. p. 113; Kütz. Sp. Alg. p. 300.)

‡ Beiträge z. Kenntniss der Nostochaceæ, Berne, 1853, p. 13.

confirmed by Dr. Montagne, in a note published by him last year on *Nostoc Boussingaultii**. For my own part I have repeated, some years since, on a terrestrial species common about Cherbourg, all the observations I formerly made upon *Nostoc Mougeotii*. In spite of the difference of station of the two plants, they were reproduced exactly in the same way, and presented exactly the same phænomena. The resemblance in this respect is so complete, that, finding no new fact demanding notice, I have thought it useless to publish these researches. If I determine to do so now, it is above all from a desire to profit by the talent of M. Riocreux to illustrate the subject by figures far more perfect than those which accompanied my preceding memoir. In the second part of this note I shall make known a mode of reproduction of another genus which offers a certain resemblance of structure to *Nostoc*, but which possesses a distinct fructification, of which the latter is destitute.

I.

Nostoc vesicarium, DC., is a small species with a globular frond, growing on the ground among mosses and blades of grass. It is met with abundantly around Cherbourg, on the coping of walls covered with earth, along turfed roads, &c. Young specimens are perfectly spherical, often combined in great numbers under the form of little grains of a blackish-green colour, the dimensions of which vary from microscopic minuteness to the size of a pea. In proportion as the plant enlarges, its frond becomes less regular; it produces convolutions and folds, and the largest specimens form sinuous expansions, resembling small specimens of *Nostoc commune*.

Under the microscope the frond presents the same structure as that of other species of *Nostoc*. It consists of a transparent gelatinous mass, smooth and firm externally, sometimes having a yellowish tinge at the borders, while within are entwined innumerable chaplets of greenish granules. These chaplets are simple, and are composed of an indefinite series of globular joints, formed of a slightly granular pale green substance. The row is interrupted at intervals by a larger globule, almost colourless or slightly yellowish, with contents more homogeneous and less refractive than those of the other joints: on each side of this globule is observed a little granulation situated at the point of contact with the adjacent joint (Pl. I. fig. 4). The chaplets are elongated by the repeated division of the green globules. Each of these, after having increased a little in the longitudinal direction of the row, is cut in half, and thus gives birth to two

* Note sur deux Algues nées pendant les expériences de M. Boussingault, Comptes Rendus, 1856, April 28.

new joints, which subsequently divide in the same way. As to the large globules, they do not divide, and they end by becoming detached from the chaplets without undergoing any change. They have long been regarded, though without any reason, as the reproductive bodies of *Nostoc*. M. Kützing even still continues to designate them by the name of *spermatia*. But this denomination, which M. Kützing, by a lamentable abuse, applies indifferently to most diverse organs, cannot be longer preserved here, any more than in many other cases where there is nothing to justify its employment. Among the different names that have been given to these large joints of the *Nostochineæ*, that of *heterocysts*, employed by Dr. Allman, seems to me the most suitable; and I shall adopt it the more willingly as it does not prejudge the function, of whose true nature we are at present ignorant.

It is during the months of September and October that we observe in *Nostoc vesicarium* the same series of phænomena that I have described in *Nostoc Mougeotii*. We at that time frequently find individuals whose contents escape in a diffluent greenish jelly, which spreads over surrounding bodies. This jelly presents exactly the aspect of a Palmellaceæ. But if a portion is placed under the microscope, we perceive that it is filled with fragments of chaplets intermixed with detached heterocysts. An attentive examination of these fragments of chaplets shows that at this epoch they are endowed with a creeping motion,—very slow, but easy to ascertain under a sufficient magnifying power. Placed in a drop of water, on a slip of glass, in front of a window, they gradually gather together at the margin of the drop nearest to the point whence the light comes. When one of these deliquescing Nostocs is placed in a saucer with a little water, the chaplets soon spread round the circumference, and form at the bottom of the saucer a greenish pellicle, as an *Oscillatoria* would do*.

If the observation of the fragments of the chaplets be continued for some days, they are soon seen to become motionless,

* The independent motion possessed by the chaplets of the deliquescing *Nostoc* did not escape Vaucher (Conferves d'eau douce, pp. 215, 216). It is especially evident in the aquatic species. At least, it appeared to me very marked in *Nostoc Mougeotii*, and Vaucher has made the same observation on *Nostoc verrucosum*. But it occurs also under the same circumstances in the terrestrial species, and I was in error in my former paper in raising some doubt upon this point. I have had particular opportunity of ascertaining it in fine specimens of *Nostoc commune*, gathered in warm damp weather in the month of June, when some portions were beginning to deliquesce. I mention this fact, because it was under the same conditions and at the same time of the year that Vaucher also observed the movement of the chaplets in this species.

and to acquire a transparent membrane (fig. 2). At the same time the green globules increase in magnitude; but this time their increase is in diameter, and no longer in the direction of the length of the chaplet. They thus become discoid: finally, they divide into two by a division which takes place in a direction opposite to that described above (fig. 3). Most of the globules divide once or twice in this way, and then the chaplet, considerably enlarged, has entirely changed its aspect. It is transformed into a transparent sac, of variable length, in which the doubled granules are arranged in parallel superposed ranks, often very distinctly and pretty regularly (fig. 4). But this regularity soon vanishes; the rows become joined together alternately; that is, the globule placed at the border of one rank becomes adherent to the globule placed above it, and the globule opposite, to that below it In this way a new chaplet is formed, wound upon itself, in the interior of the sac. At the first instant it is difficult to distinguish this arrangement of the globules. Crowded in the narrow sac which the membrane forms, and attached together more or less obliquely, they often exhibit only a confused heap. But their enchainment becomes more and more evident in proportion as the young *Nostoc* grows; the sac dilates, the new chaplet becomes elongated, and its convolutions separate, and become more distinct (fig. 5). For some time longer the young frond still presents enlargements which correspond to the situation occupied by the rows of globules: by degrees these traces are effaced, and the frond becomes developed into a transparent rounded mass, in the interior of which the chaplet turns and twists in all directions. At this epoch we may already distinguish some heterocysts among the globules. The figures comprised under the numbers 2, 3, 4 and 5 will, I think, give a sufficient idea of the different aspects presented in the transformation of a chaplet of *Nostoc* into a new individual. This phænomenon presents numerous variations of the details, upon which I consider it useless to dwell here. I shall confine myself to the following observations.

In general the terminal globules of the chaplet do not undergo the same modifications as the rest. They lose their colour like the heterocysts, and remain attached to the extremities of the chaplet, without taking part in the development I have just described. Sometimes we find them a long time after, still adherent to the surface of the young frond.

Frequently, also, one of the intermediate globules becomes transformed into a heterocyst. Sometimes even two or three are produced at different intervals in the length of the chaplet (fig. 4). The latter thus becomes divided into two or more

portions, which proceed with their development independently. Hence it is that we not unfrequently observe under the microscope, young examples of *Nostoc* attached together by an interposed heterocyst.

II.

The other *Nostochineæ* of which I have to speak belong to the genus *Cylindrospermum*, Ralfs (Kütz. *pro parte*). This genus comprehends a portion of the species which were formerly united under the name of *Anabaina*, Bory, and which consist of moniliform filaments, analogous to the chaplets of *Nostoc*, but forming an indeterminate gelatinous stratum. Certain joints of the filaments are transformed into heterocysts; others acquire an elliptical form, more considerable dimensions, and become the sporanges. The different positions which may be occupied in the filament by the sporanges and heterocysts have served to break up *Anabaina* into several genera. Those proposed by M. Kützing are too vaguely defined to be adopted without restriction. Mr. Ralfs has proposed divisions founded upon more precise conditions, which seem to me admissible*. I shall merely remark, that it is at least superfluous to separate generically plants united by such close affinities, and that it would be better to restrict the divisions established by Mr. Ralfs to the rank of subgenera, preserving the name of *Anabaina* for the whole group of species. As to the latter name, it should be maintained in any case; and Mr. Ralfs is wrong in proposing to replace it by *Trichormus*, Allm., supposing that the priority belongs to the genus *Anabæna*, established by M. Ad. de Jussieu in the family of Euphorbiaceæ. The latter was only published in 1824†, while Bory St. Vincent's genus dates from 1822‡.

In the genus *Cylindrospermum*, as defined by Mr. Ralfs, the heterocyst forms the last joint of the filament, and the sporange occupies the next joint. The filaments are endowed with a very slow but appreciable creeping motion. The joints are cylindrical; they contain a substance of a bluish-green colour, a little granular, and they multiply like those of *Nostoc*; that is to say, after having elongated in the direction of the length of the filament, they become cut in two by a transverse division. The last joint, before changing into a heterocyst, is like the rest, but the granules it contains disappear by degrees; the joint acquires a yellowish tinge, becomes larger, and assumes a more or less elongated ovoid form (fig. 8). At this epoch it is almost always

* Ann. Nat. Hist. 2nd ser. v. p. 321. pl. 8 & 9 (1850).

† De Euphorbiacearum generibus medicisque earum viribus tentamen, p. 46.

‡ Dictionnaire classique d'Histoire Naturelle, i. p. 307.

found surrounded by a few irregular mucous filaments. These filaments (*cils*), the presence of which is very common on the heterocysts of *Anabaina*, are probably nothing more than parasitic productions.

After the formation of the heterocyst, the sporange is very soon developed at the expense of the next joint. This becomes elongated, enlarged, and its contents become very granulose. By degrees its walls become thickened, and assume a brown colour. It is not, as Mr. Ralfs states, the substance contained in the sporange which takes this colour; it is merely the wall of the cell. The interior of the sporange is filled up by an elliptical spore, which may be distinguishable through the transparency of the sporange, and which preserves the green colour, as may be easily ascertained by causing it to emerge from the sporange by slight pressure. Filaments are often met with terminated at both ends by a heterocyst. It is more rare to see one filament bearing a sporange at each extremity, and in such cases it has always appeared to me that the development of one of the sporanges has preceded that of the other (fig. 9).

M. Fischer, in the memoir above cited, mentions an observation of M. Nägeli on the germination of *Cylindrospermum**. The description which he gives, besides being very short and incomplete, does not appear to agree with what I have seen myself in these plants.

The first species in which I observed the reproduction is remarkable from the rugose surfaces of its sporanges. The filaments are about $\frac{1}{3000}$ to $\frac{1}{6000}$th of an inch in diameter. It is the same plant that has been published in the 'Fasciculi' of M. Rabenhorst† under the name of *Cylindrospermum majus*, Kütz. It is possible that it may be really the species thus named in the 'Species Algarum;' but I cannot affirm anything on that point; for M. Kützing does not mention the rugose aspect of the sporanges, and the 'Tabulæ Phycologicæ' of the same author are unfortunately far from supplying the deficiencies of his diagnoses.

I found this species, in the month of June of last year, floating in a ditch in mucilaginous masses. The sporanges were abundant, of a brown colour, and appeared perfectly ripe. This circumstance induced me to place some fragments of the plant in a drop of water upon slips of glass, keeping them under a

* "In *Cylindrospermum*, Prof. Nägeli has actually observed the germination. After a longish stage of rest, a repeated division suddenly occurs in the cells; the outer thick wall is dissolved, and the young filament commences its growth by simultaneous division of all its cells."—Fischer, *l. c.* p. 7.

† Die Algen Sachsens, no. 411.

bell-glass to prevent evaporation. The filaments soon became decomposed; the heterocysts lost their colour, and were in part detached from the sporanges. A great number of the latter were also spoilt, and the spores which they contained vanished without leaving a trace. But others were preserved without any change of aspect. I continued to observe them with care, and in the course of the month of September, I had the pleasure of seeing the spore at last pierce the summit of the sporange, and become developed into a new filament, in the following manner. The spore, becoming elongated, lifted up a little piece of the internal wall of the sporange, which it pushed before it. As soon as it had made its way out, it began to exhibit septa, and to change into a torulose filament, composed of three or four joints, filled with very granular contents. The divisions of the joints are at first rather indistinct, but become more and more clear in proportion as new ones are formed. For rather a long time the fragment of the wall of the sporange which has been lifted up by the spore remains at the summit of the filament in the form of a little cap covering the last joint (fig. 12). The filament elongates simultaneously at both ends, but more rapidly at first at that which is outside the sporange. The new joints are of less diameter than those formed in the place occupied by the spore, so that the young filament is slightly attenuated at the extremities (fig. 13). By degrees, however, these differences are effaced; the joints, in multiplying, acquire dimensions more and more equal; their granules become less apparent, and the resemblance of the new filaments to the old ones is at last complete.

I have subsequently discovered that this experiment succeeds just as well, or still better, with specimens dried and preserved for several months in the herbarium, provided the spores are quite ripe. On placing them in the same way on slips of glass with a drop of water, I have seen them begin to germinate in about a fortnight. The spores of *Anabaina* therefore belong to that category of reproductive bodies which M. Al. Braun* calls *hypnospores*, and which are susceptible of development after a long period of repose, and in spite of prolonged desiccation. In many freshwater Algæ we find reproductive bodies provided with this persistence of vitality, which seems to be a condition necessary for the preservation of the plants during the alternations of drought and humidity to which they are exposed; but none, I think, are better endowed in this respect than the species of *Anabaina*, as the following example will show.

In the month of April 1848, I gathered fine specimens, well in fruit, of *Anabaina licheniformis*, Bory (*Cylindrospermum*

* Algarum unicell. genera nova, p. 16.

licheniforme, Kütz.). In this species the sporanges are smooth, and of a deep brownish red when they are perfectly ripe. In the spring of the present year (1857), I detached a few fragments of these specimens, which I had preserved in the herbarium for nine years, and subjected them to the same experiments as the preceding. A fortnight had scarcely elapsed when a great number of sporanges began to open, and to emit the summit of the young filament. I have repeated this experiment several times with the same success; and in those which I made this summer, I have often seen the spores germinate at the end of six or seven days. The germination of this species exactly resembles that of the preceding. Only the little portion of the wall of the sporange, lifted up by the spore like an operculum, is not carried away at the summit of the filament, but remains attached laterally upon the sporange (fig. 7).

I should have desired to have made the same trials with specimens of still greater age. It would be interesting to ascertain how long a time the spores of *Anabaina* can preserve their faculty of germination. But the success of these experiments requires, as I have said before, that the spores shall be perfectly ripe. Now, it is more rare than one would suppose, to find them in this state in herbaria. I have assured myself of this by examining all the specimens in my collection and that of Bory St. Vincent; and this difficulty has prevented me from carrying my researches any further.

EXPLANATION OF PLATE I.

[All the figures are magnified 330 diameters.]

Fig. 1. Two of the filaments or chaplets filling the interior of *Nostoc vesicarium*, DC.

Fig. 2. Chaplet clothed by a transparent membrane.

Fig. 3. Chaplet, of which the globules are enlarged and beginning to divide.

Fig. 4. Chaplet with the multiplication of the globules more advanced.

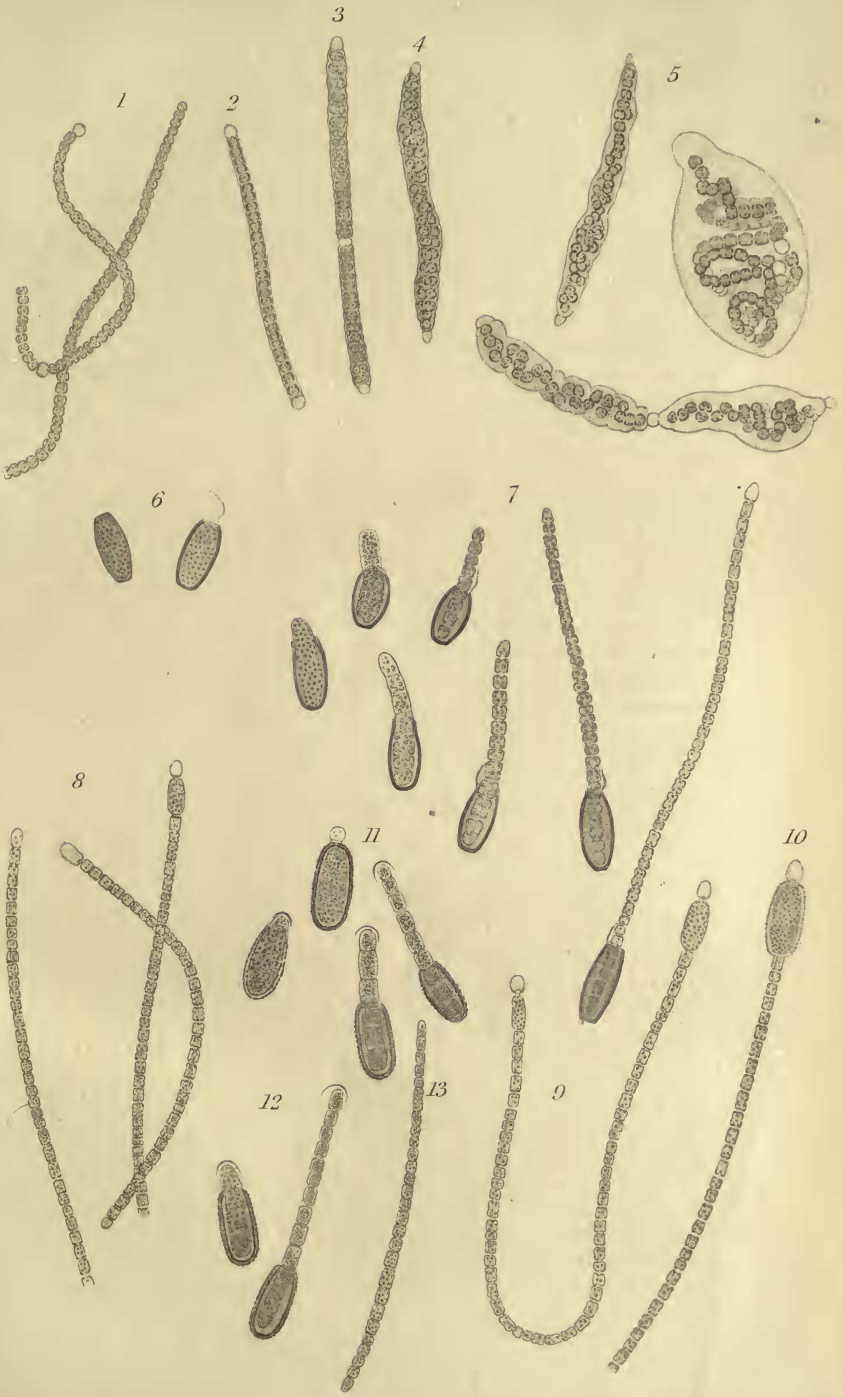
Fig. 5. Course of development of the chaplets into new fronds.

Fig. 6. Two sporanges of *Anabaina* (*Cylindrospermum*) *licheniformis*, Bory. That on the left contains a spore; the other is empty. The membrane of the latter exhibits slight punctations.

Fig. 7. Germination of the same. The spore pierces the summit of the sporange, and elongates into a moniliform filament, which soon becomes similar to that of the mother-plant.

Fig. 8. The filaments of *A.* (*Cylindrospermum*) *major*, Kütz., in different states. That on the left is the youngest. The terminal joint, rounded at the free extremity, is beginning to change into a heterocyst. In the next the heterocyst is already formed, and surrounded by a few mucous threads. In the third the sporange is beginning to develope.

Fig. 9. Filament with a sporange formed at each extremity.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